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IMAGE PREDICTIVE CODING METHOD

VERIFICATION OF ENGLISH TRANSLATION

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Sir:

I, Kazuhiko YASUI of c/o Aoyama & Partners, IMP Building, 1-3-7, Shiromi, Chuo-ku, Osaka 540-0001 Japan, declare that I am conversant in both the Japanese and English languages and that the English translation as attached hereto is an accurate translation of Japanese Patent Application No. P8-176426 filed on July 5, 1996.

February 12, 2008

Kazuhiko YASUI

PATENT OFFICE
JAPANESE GOVERNMENT

This is to certify that the annexed is a true copy of the following application as filed with this Office.

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Title of the Invention:

ADAPTIVE INTRA-FRAME PREDICTION METHOD IN IMAGE TRANSFORM DOMAIN

Claims:

1. An adaptive intra-frame prediction method in an image transform domain for improving image coding efficiency, including the following steps of:

sampling an inputted image into a plurality of blocks each including pixels of a two-dimensional array;

transforming the sampled pixel blocks into a transform domain;

forming prediction blocks for the transformed blocks by using information from blocks which have been previously restored and stored in a block memory;

making a decision as to which is the most efficient prediction block to be used and transmitting this decision to a decoder in a form of a designator bit;

subtracting the selected prediction block from the current block, thereby making a prediction error signal based on the decision;

quantizing the prediction error signal;

coding in an entropy coding manner the quantized prediction error signal and transmitting the coded information to the decoder;

inverse quantizing the quantized prediction error signal;

forming a restoration block of coefficients by adding the prediction block to the inverse quantized error signal, and restoring the coefficients of the current block;

storing the coefficients of the restored block for future prediction into the block memory; and

inverse transforming the coefficients of the block for obtaining a restored pixel domain block.

2. An adaptive intra-frame prediction method in an image transform domain for improving image coding efficiency, including the following steps of:

sampling an inputted image into a plurality of blocks each including pixels of a two-dimensional array;

transforming the sampled pixel blocks into a transform domain;

quantizing coefficients of the transform domain;

forming prediction blocks for the blocks of the quantized transform coefficients by using information from blocks which have been previously restored and stored in a block memory;

making a decision as to which is the most efficient prediction block to be used and transmitting this decision to a decoder in a form of a designator bit;

subtracting the selected prediction block from the current block, thereby making a prediction error signal based on the decision;

coding in an entropy coding manner the prediction error signal and transmitting the coded information to the decoder;

forming a restoration block having quantized coefficients by adding the same prediction block to the prediction error signal, and restoring the current block having quantized coefficients;

storing the restored block having the quantized coefficients for future prediction into the block memory;

inverse quantizing the quantized coefficients; and

inverse transforming the inverse quantized coefficients for obtaining a restored pixel domain block.

3. An adaptive intra-frame prediction method in an image transform domain for improving image coding efficiency, including the following steps of:

sampling an inputted image into a plurality of blocks each including pixels of a two-dimensional array;

subjecting a block of pixels to a motion compensation step to make a block of motion-compensation prediction error signals;

transforming the block of motion-compensation

prediction error signals into a transform domain;

forming prediction blocks for the blocks of transformed coefficients by using information from blocks which have been previously restored and stored in a block memory;

making a decision as to which is the most efficient prediction block to be used and transmitting this decision to a decoder in a form of a designator bit;

subtracting the selected prediction block from the current block, thereby making a prediction error signal based on the decision;

quantizing the prediction error signal;

coding in an entropy coding manner the quantized prediction error signal and transmitting the coded information to the decoder;

inverse quantizing the quantized prediction error signal;

forming coefficients of the restored block by adding the prediction block to the inverse quantized prediction signal, and restoring the coefficients of the current block;

storing the coefficients of the restored block for future prediction into the block memory;

inverse transforming the coefficients of the block for restoring the prediction signal that has

undergone a motion compensation of a pixel domain; and

determining a block of restored pixels by adding the motion-compensated prediction to the restored prediction error signal of motion compensation.

4. An adaptive intra-frame prediction method in an image transform domain for improving image coding efficiency, including the following steps of:

sampling an inputted image into a plurality of blocks each including pixels of a two-dimensional array;

subjecting a block of pixels to a motion compensation step to make a block of motion-compensation prediction error signals;

transforming the block of motion-compensation prediction error signals into a transform domain;

quantizing transform domain coefficients;

forming prediction blocks for the blocks of the quantized transform coefficients by using information from blocks which have been previously restored and stored in a block memory;

making a decision as to which is the most efficient prediction block to be used and transmitting this decision to a decoder in a form of a designator bit;

subtracting the selected prediction block from the current block, thereby making a prediction error signal based on the decision;

coding in an entropy coding manner the quantized prediction error signal and transmitting the coded information to the decoder;

forming a restored block having quantized coefficients by adding the same prediction block to the error signal, and restoring the current block having quantized coefficients;

storing the restored block of the quantized coefficients in the block memory for future prediction;

inverse quantizing the quantized coefficients;

inverse transforming the inverse quantized coefficients for determining a prediction error that has undergone a motion compensation of a restoration pixel domain; and

determining a block of restored pixels by adding the motion-compensated prediction to the restored motion-compensated prediction error signal.

5. The adaptive intra-frame prediction method in the image transform domain as claimed in Claim 1, further including the following steps of:

extracting designator bit information from a bit stream;

forming prediction blocks for the blocks of transform coefficients based on the designator bit, and using information derived from blocks which have been

previously restored and stored in the block memory;

coding in an inverse entropy coding manner the bit stream to obtain a series of decoded events;

inverse scanning decoded events among quantized prediction errors;

inverse quantizing the quantized prediction errors;

restoring coefficients of the current block by adding the prediction block to the inverse quantized prediction error to make coefficients of the restored block;

storing the coefficients of the restored block in the block memory for future prediction;

inverse transforming the coefficients of the block to obtain a restoration block of a pixel domain; and

restoring a decoded image.

6. The adaptive intra-frame prediction method in the image transform domain as claimed in Claim 2, further including the following steps of:

extracting designator bit information from a bit stream;

forming a prediction block for the quantized transform coefficients of the block based on the designator bit, and using information derived from blocks which have been previously restored and stored in the block memory;

coding in an inverse entropy coding manner the bit stream to obtain a series of decoded events;

inverse scanning decoded events among quantized prediction errors;

restoring a current block of the quantized coefficients by adding the prediction block to the quantized prediction error to make a restored block having the quantized coefficients;

storing the restored block having the quantized coefficients in the block memory for future prediction;

inverse quantizing the quantized coefficients;

inverse transforming the inverse quantized coefficients for obtaining a restored pixel domain block; and

restoring a decoded image.

7. The adaptive intra-frame prediction method in the image transform domain as claimed in Claim 3, further including the following steps of:

extracting designator bit information from a bit stream;

forming prediction blocks for the blocks of transform coefficients based on the designator bit, and using information derived from blocks which have been previously restored and stored in the block memory;

coding in an inverse entropy coding manner the

bit stream to obtain a series of decoded events;

inverse scanning decoded events among a plurality of quantized prediction errors;

inverse quantizing the quantized prediction errors;

restoring coefficients of the current block by adding the prediction block to the inverse quantized prediction error to make coefficients of the restored block;

storing the coefficients of the restored block in the block memory for future prediction;

inverse transforming the coefficients of the block for restoring the prediction error that has undergone a motion compensation of a pixel domain;

determining pixels of the restored block by adding the motion-compensated prediction to the restored prediction error signal of motion compensation; and

restoring a decoded image.

8. The adaptive intra-frame prediction method in the image transform domain as claimed in Claim 4, further including the following steps of:

extracting designator bit information from a bit stream;

forming prediction blocks for the blocks of transform coefficients based on the designator bit, and

using information derived from blocks which have been previously restored and stored in the block memory;

coding in an inverse entropy coding manner the bit stream to obtain a series of decoded events;

inverse scanning decoded events among a plurality of blocks of quantized prediction errors;

restoring a current block having quantized coefficients by adding the prediction block to the quantized prediction error to make a restored block having the quantized coefficients;

storing the quantized and restored block in the block memory for future prediction;

inverse quantizing the quantized coefficients;

inverse transforming the inverse quantized coefficients for obtaining a motion-compensated prediction error of a restored pixel domain;

determining a block of restored pixels by adding the motion-compensated prediction to the restored motion-compensated prediction error signal; and

restoring a decoded image.

9. The adaptive intra-frame prediction method in the image transform domain as claimed in any one of Claims 1, 2, 3 or 4,

wherein the step of sampling an inputted image into a plurality of blocks each including pixels of a two-

dimensional array further includes an interleave step for alternately inserting pixels,

wherein pixels of the two-dimensional array in a group of four blocks are rearranged so as to be comprised of odd-numbered pixels located in odd-numbered rows in a first block, comprised of even-numbered pixels located in the odd-numbered rows in a second block, comprised of odd-numbered pixels located in even-numbered rows in a third block, and comprised of even-numbered pixels located in the even-numbered rows in a fourth block.

10. The adaptive intra-frame prediction method in the image transform domain as claimed in any one of Claims 1, 2, 3, 4, 5, 6, 7 or 8,

wherein the prediction block is selected from blocks which have been previously restored, stored in the block memory and located adjacently to the coded current block, and all coefficient data in the block are selected.

11. The adaptive intra-frame prediction method in the image transform domain as claimed in any one of Claims 1, 2, 3, 4, 5, 6, 7 or 8,

wherein the prediction block is selected from blocks which have been previously restored, stored in the block memory and located adjacently to the coded current block, and a predetermined subset is selected as the coefficient data of the block.

12. The adaptive intra-frame prediction method in the image transform domain as claimed in any one of Claims 1, 2, 3, 4, 5, 6, 7 or 8,

wherein the prediction block is selected from blocks which have been previously restored, stored in the block memory and located upwardly or leftwardly adjacent to the coded current block, only the coefficient data of the top row of the block and the leftmost column of the block are used and the remaining coefficient data are set to zero.

13. The adaptive intra-frame prediction method in the image transform domain as claimed in any one of Claims 1, 2, 3, 4, 5, 6, 7 or 8,

wherein the prediction block is selected from blocks which have been previously restored, stored in the block memory and located in the vicinity of the coded current block, and the coefficient data of the blocks are weighted by different weighting functions.

14. The adaptive intra-frame prediction method in the image transform domain as claimed in any one of Claims 1, 2, 3, 4, 5, 6, 7 or 8,

wherein the prediction block is selected from blocks which have been previously restored, stored in the block memory and located in the vicinity of the coded current block, and the coefficient data of the blocks are

subjected to transform operation.

15. The adaptive intra-frame prediction method in the image transform domain as claimed in any one of Claims 1, 2, 3, 4, 5, 6, 7 or 8,

wherein the prediction block is a block which has been previously restored, stored in said block memory and obtained through weighted averaging of a plurality of blocks located in the vicinity of the coded current block.

16. The adaptive intra-frame prediction method in the image transform domain as claimed in any one of Claims 1, 2, 3 or 4,

wherein the decision of the most efficient prediction block to be used includes the following steps of:

scanning a different prediction error block among a series of run level events;

coding the events in an entropy coding manner;

determining all bits to be used for the different prediction error block;

comparing bits used for the different prediction error block; and

selecting a prediction block corresponding to the prediction block having the smallest number of bits.

17. The adaptive intra-frame prediction method in the image transform domain as claimed in any one of

Claims 1, 2, 3, 4, 5, 6, 7 or 8,

wherein the step of storing and restoring a decoded image by making pixels of the two-dimensional array from a plurality of groups of four interleaved blocks further includes the following steps of: determining odd-numbered pixels located in odd-numbered rows from a first block; determining even-numbered pixels located in the odd-numbered rows from a second block; determining odd-numbered pixels located in even-numbered rows from a third block; determining even-numbered pixels located in the even-numbered rows from a fourth block; and returning pixels from the interleave.

18. The adaptive intra-frame prediction method in the image transform domain as claimed in any one of Claims 1, 2, 3, 4, 5, 6, 7 or 8,

wherein the transform used is discrete cosine transform.

Detailed Description of the Invention:

[0001]

Field of the Invention:

The present invention relates to a method used for coding of static images and coding of dynamic images, and more particularly, the invention relates to an adaptive intra-frame prediction method in an image transform domain involved in a process of performing image coding in steps

of block.

[0002]

Prior Art:

The image coding has been widely used in many international standards such as JPEG, MPEG1, H.261, MPEG2 and H.263. Each of the latter standards has a more improved coding efficiency. That is, much effort has been devoted to further reducing the number of bits than in the conventional standards in expressing the same image quality.

[0003]

The image coding on dynamic images is comprised of intra-frame coding and prediction frame coding. In a representative hybrid coding system such as MPEG1 Standard, continuous frames can be classified into the following three different types: intra-frame ("I-frame"), prediction frame ("P-frame") and bidirectional prediction frame ("B-frame"). The I-frame is coded independent of the other frames, i.e., the I-frame is compressed without using the other frames. The P-frame is coded through motion detection and compensation by using the immediately preceding frame for the purpose of predicting the contents of a coded frame (it is a P-frame). The B-frame is coded through motion detection and compensation by using information from the immediately preceding frame and

information from the subsequent frame for predicting the data of the contents of the B-frame. The preceding frame and the subsequent frame is the I-frame or the P-frame. The I-frame belongs to an intra-code mode. The P-frame and the B-frame belong to a prediction code mode.

[0004]

As the characteristics of the coding of the I-frame, the P-frame and the B-frame are different from one another, the compressing methods thereof differ from one another. The I-frame uses no temporary prediction for the purpose of reducing the redundancy, and therefore, it requires more bits than those of the P-frame and the B-frame.

[0005]

A description will be herein made taking MPEG2 as an example. It is assumed that the bit rate is 4 Mbits/sec and an image having 30 frames/sec is used. In general, the ratio of the number of bits used for the I- P- and B-frames is 6 : 3 : 1. Therefore, the I-frame uses about 420 kbits/s, and the B-frame uses about 70 kbits/s. This is because the B-frame is sufficiently predicted from both directions.

[0006]

Since DCT (Discrete Cosine Transform) transform is executed on a block basis, the recent image coding

methods are all based on the division of an image into smaller blocks. According to the intra-frame coding, an inputted digital image is first subjected to a block sampling process as shown in Fig. 1. The blocks are subjected to quantizing coding, run length Huffman variable length coding (VLC) and subsequently to a DCT transform process. As the prediction frame coding, an inputted digital image is subjected to motion compensation, and the motion-compensated block (i.e., the predicted block) is subjected to the DCT transform process. Next, the quantizing coding and the run length Huffman VLC coding are executed.

[0007]

The fact that the block-based DCT transform process removes or reduces the intra-block spatial redundancy is practiced by the actual image coding techniques. Further, the motion detection and compensation removes or reduces a temporary redundancy between adjacent frames. Further, the run length Huffman VLC coding or another entropy coding executed after the DCT transform and the quantizing process removes a statistical redundancy between quantized DCT transform coefficients. However, the process is executed only on the intra-block basis.

[0008]

A digital image has a great spatial redundancy as

an inherent characteristic. This redundancy exists not only in the intra-frame blocks inside an image but also between blocks over blocks. However, the fact that no actual method uses a process for removing the redundancy between blocks of an image is apparent from the above description.

[0009]

Therefore, it can be predicted that the image coding efficiency can be further improved by removing not only the redundancy between two images or the insides of two blocks in one image but also the redundancy between two blocks in one image.

[0010]

Problems to be Solved by the Invention:

According to the existing image coding method, the DCT or another transform process is executed on the block basis due to restrictive conditions in terms of hardware formation and calculation.

[0011]

Although the spatial redundancy is reduced through the block-based transform process, it is restricted to the inside of one block. The redundancy between adjacent two blocks is not satisfactorily considered, however, it can be further reduced when the intra-frame coding which consistently consumes a great number of bits

is used.

[0012]

Accordingly, an object of the present invention is to solve the inefficiency of the conventional coding methods. The point for solution is how the intra-block redundancy is removed by introducing a proper inside prediction to the transform domain.

[0013]

Means for Solving the Problems:

The present inventor has discovered that the DCT transform coefficients located in the same positions of adjacent blocks closely resemble each other in many cases. The present inventor has also discovered that the resemblance is great particularly in a case where the original image compositions of two blocks closely resemble each other or when an identical image pattern of, for example, a straight line, an angle and so forth is included. Identical information means a redundancy according to an information theory.

[0014]

This kind of redundancy existing in the DCT transform domain over a block can be removed or remarkably reduced by adaptive intra-frame prediction from a previous block. Then, the following VLC entropy coding process can achieve a higher coding efficiency by virtue of the smaller

entropy of prediction.

As a result of prediction of this DCT transform domain, input of redundant data to a VLC entropy coding circuit can be remarkably reduced. Accordingly, there can be expected a great saving of bits. Therefore, the image quality of the coded image data is definitely improved.

[0015]

The present invention provides a system for accurately predicting DCT transform coefficients from another block. This system is able to remove the redundancy existing over the adjacent block, further reduce the entropy of the quantized DCT transform coefficients and consequently reduce the number of bits required for coding the DCT transform coefficients.

The DCT transform coefficients of the target current block to be processed at the present time point can be predicted from the DCT transform coefficients of the same position in the preceding adjacent block. The adjacent block has already been decoded in the processing stage. That is, according to the first DC coefficients in one of previously decoded adjacent blocks, a first DC coefficient is predicted. A second coefficient AC1 is predicted from the second coefficient AC1 in the same decoded block. The same operation will be executed subsequently. By using this method, several predicted

blocks can be obtained from the adjacent decoded blocks located upwardly on the left-hand side, diagonally on the left-hand side, upwardly diagonally on the right-hand side and upwardly with respect to the DCT transform block that is coded at the present time point. These predicted blocks are checked by being subjected to the actual entropy coding. Then, a prediction block having a smaller number of bits is selected, thereafter subjected to the entropy coding and transmitted to the decoder together with an additional designator bit. The decoder is informed of the adjacent block from which the current block is predicted.

[0016]

A method according to the present invention can predict the DCT transform coefficients of the current block. The DCT transform coefficients generally has satisfactory interrelationships with the DCT transform coefficients of another adjacent block. The reason therefor is that the DCT transform tends to give an identical value or an identical DCT transform coefficients distribution to a similar block image.

[0017]

Inputted image data of an intra-frame or temporarily predicted frame is normally subjected first to a block-based DCT process. After the DCT transform coefficients of the current block is obtained, a DCT domain

predicting process can be executed before quantization or after quantization.

As shown in Fig. 2, the DCT transform coefficients of the current block can be predicted from blocks that are the already decoded blocks and adjacent blocks, i.e., an upper left-hand block B1, an upper block B2, an upper right-hand block B3 and a left-hand block B4. A predicted block can be obtained by subtracting all the DCT transform coefficients of the current block from all the DCT transform coefficients of the preceding adjacent block located in the same position. The block can also be obtained by partially subtracting the DCT transform coefficients instead of all the DCT transform coefficients.

[0018]

The predicted DCT transform coefficients of different predicted blocks are quantized if the prediction is executed before the quantization. Then, the DCT transform coefficients are subjected to the entropy coding process. The entropy coding process is identical to that of the encoder, and it is checked which predicted block is used as a low order bit.

The prediction block which uses the low order bit is selected, and the selected prediction block is coded in an entropy coding manner together with a designator bit for informing the decoder of the prediction determination.

[0019]

In the decoder, the block predicted by the designator bit is decoded. That is, the DCT transform coefficients predicted for one block is decoded in an inverse entropy decoding manner, and thereafter the DCT transform coefficients of the block are obtained by adding reference DCT transform coefficients of the adjacent block which has previously been decoded. This is informed by the designator bit. Finally, an inverse DCT transform process is applied to the restored DCT transform coefficients of each block, so that a decoded image is obtained.

[0020]

In the first aspect of the present invention, there is provided an adaptive intra-frame prediction method in an image transform domain for improving image coding efficiency, including the following steps of:

sampling an inputted image into a plurality of blocks each including pixels of a two-dimensional array;

transforming the sampled pixel blocks into a transform domain;

forming prediction blocks for the transformed blocks by using information from blocks which have been previously restored and stored in a block memory;

making a decision as to which is the most efficient prediction block to be used and transmitting this

decision to a decoder in a form of a designator bit;

subtracting the selected prediction block from the current block, thereby making a prediction error signal based on the decision;

quantizing the prediction error signal;

coding in an entropy coding manner the quantized prediction error signal and transmitting the coded information to the decoder;

inverse quantizing the quantized prediction error signal;

forming a restoration block of coefficients by adding the prediction block to the inverse quantized error signal, and restoring the coefficients of the current block;

storing the coefficients of the restored block for future prediction into the block memory; and

inverse transforming the coefficients of the block for obtaining a restored pixel domain block.

[0021]

In the second aspect of the present invention, there is provided an adaptive intra-frame prediction method in an image transform domain for improving image coding efficiency, including the following steps of:

sampling an inputted image into a plurality of blocks each including pixels of a two-dimensional array;

transforming the sampled pixel blocks into a transform domain;

quantizing coefficients of the transform domain;

forming prediction blocks for the blocks of the quantized transform coefficients by using information from blocks which have been previously restored and stored in a block memory;

making a decision as to which is the most efficient prediction block to be used and transmitting this decision to a decoder in a form of a designator bit;

subtracting the selected prediction block from the current block, thereby making a prediction error signal based on the decision;

coding in an entropy coding manner the prediction error signal and transmitting the coded information to the decoder;

forming a restoration block having quantized coefficients by adding the same prediction block to the prediction error signal, and restoring the current block having quantized coefficients;

storing the restored block having the quantized coefficients for future prediction into the block memory;

inverse quantizing the quantized coefficients; and

inverse transforming the inverse quantized

coefficients for obtaining a restored pixel domain block.

[0022]

In the third aspect of the present invention, there is provided an adaptive intra-frame prediction method in an image transform domain for improving image coding efficiency, including the following steps of:

sampling an inputted image into a plurality of blocks each including pixels of a two-dimensional array;

subjecting a block of pixels to a motion compensation step to make a block of motion-compensation prediction error signals;

transforming the block of motion-compensation prediction error signals into a transform domain;

forming prediction blocks for the blocks of transformed coefficients by using information from blocks which have been previously restored and stored in a block memory;

making a decision as to which is the most efficient prediction block to be used and transmitting this decision to a decoder in a form of a designator bit;

subtracting the selected prediction block from the current block, thereby making a prediction error signal based on the decision;

quantizing the prediction error signal;

coding in an entropy coding manner the quantized

prediction error signal and transmitting the coded information to the decoder;

inverse quantizing the quantized prediction error signal;

forming coefficients restored block by adding the prediction block to the inverse quantized prediction signal, and restoring the coefficients of the current block;

storing the coefficients of the restored block for future prediction into the block memory;

inverse transforming the coefficients of the block for restoring the prediction signal that has undergone a motion compensation of a pixel domain; and

determining a block of restored pixels by adding the motion-compensated prediction to the restored prediction error signal of motion compensation.

[0023]

In the fourth aspect of the present invention, there is provided an adaptive intra-frame prediction method in an image transform domain for improving image coding efficiency, including the following steps of:

sampling an inputted image into a plurality of blocks each including pixels of a two-dimensional array;

subjecting a block of pixels to a motion compensation step to make a block of motion-compensation

prediction error signals;

transforming the block of motion-compensation prediction error signals into a transform domain;

quantizing a transform domain coefficients;

forming prediction blocks for the blocks of the quantized transform coefficients by using information from blocks which have been previously restored and stored in a block memory;

making a decision as to which is the most efficient prediction block to be used and transmitting this decision to a decoder in a form of a designator bit;

subtracting the selected prediction block from the current block, thereby making a prediction error signal based on the decision;

coding in an entropy coding manner the quantized prediction error signal and transmitting the coded information to the decoder;

forming a restored block having quantized coefficients by adding the same prediction block to the error signal, and restoring the current block having quantized coefficients;

storing the restored block of the quantized coefficients in the block memory for future prediction;

inverse quantizing the quantized coefficients;

inverse transforming the inverse quantized

coefficients for determining a prediction error that has undergone a motion compensation of a restoration pixel domain; and

determining a block of restored pixels by adding the motion-compensated prediction to the restored motion-compensated prediction error signal.

[0024]

In the fifth aspect of the present invention, there is provided an adaptive intra-frame prediction method in an image transform domain according to the first aspect of the invention, further including the following steps of:

extracting designator bit information from a bit stream;

forming prediction blocks for the blocks of transform coefficients based on the designator bit, and using information derived from blocks which have been previously restored and stored in the block memory;

coding in an inverse entropy coding manner the bit stream to obtain a series of decoded events;

inverse scanning decoded events among quantized prediction errors;

inverse quantizing the quantized prediction errors;

restoring coefficients of the current block by adding the prediction block to the inverse quantized

prediction error to make coefficients of the restored block;

storing the coefficients of the restored block in the block memory for future prediction;

inverse transforming the coefficients of the block to obtain a restoration block of a pixel domain; and

restoring a decoded image.

[0025]

In the sixth aspect of the present invention, there is provided an adaptive intra-frame prediction method in an image transform domain according to the second aspect of the invention, further including the following steps of:

extracting designator bit information from a bit stream;

forming a prediction block for the quantized transform coefficients of the block based on the designator bit, and using information derived from blocks which have been previously restored and stored in the block memory;

coding in an inverse entropy coding manner the bit stream to obtain a series of decoded events;

inverse scanning decoded events among quantized prediction errors;

restoring a current block of the quantized coefficients by adding the prediction block to the quantized prediction error to make a restored block having

the quantized coefficients;

storing the restored block having the quantized coefficients in the block memory for future prediction;

inverse quantizing the quantized coefficients;

inverse transforming the inverse quantized coefficients for obtaining a restored pixel domain block; and

restoring a decoded image.

[0026]

In the seventh aspect of the present invention, there is provided an adaptive intra-frame prediction method in an image transform domain according to the third aspect of the invention, further including the following steps of:

extracting designator bit information from a bit stream;

forming prediction blocks for the blocks of transform coefficients based on the designator bit, and using information derived from blocks which have been previously restored and stored in the block memory;

coding in an inverse entropy coding manner the bit stream to obtain a series of decoded events;

inverse scanning decoded events among a plurality of quantized prediction errors;

inverse quantizing the quantized prediction errors;

restoring coefficients of the current block by adding the prediction block to the inverse quantized prediction error to make coefficients of the restored block;

storing the coefficients of the restored block in the block memory for future prediction;

inverse transforming the coefficients of the block for restoring the prediction error that has undergone a motion compensation of a pixel domain;

determining pixels of the restored block by adding the motion-compensated prediction to the restored prediction error signal of motion compensation; and

restoring a decoded image.

[0027]

In the eighth aspect of the present invention, there is provided an adaptive intra-frame prediction method in an image transform domain according to the fourth aspect of the invention, further including the following steps of:

extracting designator bit information from a bit stream;

forming prediction blocks for the blocks of transform coefficients based on the designator bit, and using information derived from blocks which have been previously restored and stored in the block memory;

coding in an inverse entropy coding manner the

bit stream to obtain a series of decoded events;

inverse scanning decoded events among a plurality of blocks of quantized prediction errors;

restoring a current block having quantized coefficients by adding the prediction block to the quantized prediction error to make a restored block having the quantized coefficients;

storing the quantized and restored block in the block memory for future prediction;

inverse quantizing the quantized coefficients;

inverse transforming the inverse quantized coefficients for obtaining a motion-compensated prediction error of a restored pixel domain;

determining a block of restored pixels by adding the motion-compensated prediction to the restored motion-compensated prediction error signal; and

restoring a decoded image.

[0028]

In the ninth aspect of the present invention, there is provided an adaptive intra-frame prediction method in an image transform domain according to any one of the first, second, third or fourth aspect of the invention,

wherein the step of sampling an inputted image into a plurality of blocks each including pixels of a two-dimensional array further includes an interleave step for

alternately inserting pixels,

wherein pixels of the two-dimensional array in a group of four blocks are rearranged so as to be comprised of odd-numbered pixels located in odd-numbered rows in a first block, comprised of even-numbered pixels located in the odd-numbered rows in a second block, comprised of odd-numbered pixels located in even-numbered rows in a third block and comprised of even-numbered pixels located in the even-numbered rows in a fourth block.

[0029]

In the tenth aspect of the present invention, there is provided an adaptive intra-frame prediction method in an image transform domain according to any one of the first, second, third, fourth, fifth, sixth, seventh or eighth aspect of the invention,

wherein the prediction block is selected from blocks which have been previously restored, stored in the block memory and located adjacently to the coded current block, and all coefficient data in the block are selected.

[0030]

In the eleventh aspect of the present invention, there is provided an adaptive intra-frame prediction method in an image transform domain according to any one of the first, second, third, fourth, fifth, sixth, seventh or eighth aspect of the invention,

wherein the prediction block is selected from blocks which have been previously restored, stored in the block memory and located adjacently to the coded current block, and a predetermined subset is selected as the coefficient data of the block.

[0031]

In the twelfth aspect of the present invention, there is provided an adaptive intra-frame prediction method in an image transform domain according to any one of the first, second, third, fourth, fifth, sixth, seventh or eighth aspect of the invention,

wherein the prediction block is selected from blocks which have been previously restored, stored in the block memory and located upwardly or leftwardly adjacent to the coded current block, only the coefficient data of the top row of the block and the leftmost column of the block are used and the remaining coefficient data are set to zero.

[0032]

In the thirteenth aspect of the present invention, there is provided an adaptive intra-frame prediction method in an image transform domain according to any one of the first, second, third, fourth, fifth, sixth, seventh or eighth aspect of the invention,

wherein the prediction block is selected from

blocks which have been previously restored, stored in the block memory and located in the vicinity of the coded current block, and the coefficient data of the blocks are weighted by different weighting functions.

[0033]

In the fourteenth aspect of the present invention, there is provided an adaptive intra-frame prediction method in an image transform domain according to any one of the first, second, third, fourth, fifth, sixth, seventh or eighth aspect of the invention,

wherein the prediction block is selected from blocks which have been previously restored, stored in the block memory and located in the vicinity of the coded current block, and the coefficient data of the blocks are subjected to transform operation.

[0034]

In the fifteenth aspect of the present invention, there is provided an adaptive intra-frame prediction method in an image transform domain according to any one of the first, second, third, fourth, fifth, sixth, seventh or eighth aspect of the invention,

wherein the prediction block is a block which has been previously restored, stored in said block memory and obtained through weighted averaging of a plurality of blocks located in the vicinity of the coded current block.

[0035]

In the sixteenth aspect of the present invention, there is provided an adaptive intra-frame prediction method in an image transform domain according to any one of the first, second, third or fourth aspect of the invention,

wherein the decision of the most efficient prediction block to be used includes the following steps of:

scanning a different prediction error block among a series of run level events;

coding the events in an entropy coding manner;

determining all bits to be used for the different prediction error block;

comparing bits used for the different prediction error block; and

selecting a prediction block corresponding to the prediction block having the smallest number of bits.

[0036]

In the seventeenth aspect of the present invention, there is provided an adaptive intra-frame prediction method in an image transform domain according to any one of the first, second, third, fourth, fifth, sixth, seventh or eighth aspect of the invention,

wherein the step of storing and restoring a decoded image by making pixels of the two-dimensional array

from a plurality of groups of four interleaved blocks further includes the following steps of: determining odd-numbered pixels located in odd-numbered rows from a first block; determining even-numbered pixels located in the odd-numbered rows from a second block; determining odd-numbered pixels located in even-numbered rows from a third block; determining even-numbered pixels located in the even-numbered rows from a fourth block, and returning pixels from the interleave.

[0037]

In the eighteenth aspect of the present invention, there is provided an adaptive intra-frame prediction method in an image transform domain according to any one of first, second, third, fourth, fifth, sixth, seventh or eighth aspect of the invention,

wherein the transform used is discrete cosine transform.

[0038]

Embodiments of the Invention:

The present invention provides an image coding method capable of reducing the redundancy of the other types existing in the DCT domain over the adjacent block in addition to the spatial redundancy which is normally removed by a transform such as DCT transform, the redundancy which is removed between frames by motion

detection and compensation and the statistical redundancy which is removed through the entropy coding among quantization transform coefficients inside a block.

More preferred embodiments of the present invention are described with reference to Figs. 1, 2, 3, 4, 5 and 6.

[0039]

As is apparent from Fig. 1, the encoder which is generally used for the prior art image coding (e.g., the MPEG) includes a block sampling unit 1, a DCT unit 4, a quantizing unit 5 and an entropy coding unit 6.

According to the intra-frame coding, an inputted image is subjected first to a block sampling process. Next, a DCT process is directly executed. Subsequently, a quantizing process and an entropy coding process are executed. On the other hand, according to the inter-frame coding (prediction frame coding), the image at the present time point is subjected to the processes of a motion detecting unit 2 and a motion compensating unit 3 after a block sampling process and is further subjected to a DCT process. Further, a quantizing process and an entropy coding process are executed.

[0040]

A rate controller unit 7 feeds back the bit used for the previously coded block, controls and adjusts the

quantizing process. The inverse quantizing process and the inverse DCT transform process are executed in the units 8 and 9 which serve as parts of the local decoder. The image decoded by the local decoder is stored into a unit 10, i.e., in a local decoding frame memory and used for a motion detecting process. A unit 11 is a reference frame memory for saving the preceding original frame for motion detection.

Finally, a bit stream is outputted from the unit 6 and transmitted to the decoder.

[0041]

An arrangement that four 8 × 8 DCT blocks constitutes a macro block in the DCT domain is shown in the figure. In this case, B0 indicates a current block at the present time point having 8 × 8 DCT transform coefficients. B2 indicates an already decoded block located adjacently on the upper side. B1 and B3 indicate already decoded two blocks located adjacently diagonally on the upper side. B4 indicates the preceding block located adjacently on the left-hand side. Fig. 2 shows the fact that the block having DCT transform coefficients can be predicted from the adjacent decoded blocks having the 8 × 8 DCT transform coefficients.

[0042]

Attention must be paid to the fact that the block

used for the prediction of the current block is always different. Therefore, a determination is executed on the basis of "least bit use rule", and the determination is adaptively given to different blocks on the encoder side. The decoder is informed of the determination by a designator bit.

The DCT domain prediction can be executed after or before the quantization.

[0043]

Fig. 3 shows that the DCT domain predicting process is executed after the quantizing process. An inputted image is subjected first to block sampling by a unit 12. Then, according to the intra-frame coding, the sampled block image signal passes through a unit 13. On the other hand, according to the prediction frame coding, the sampled block image signal is subtracted from the motion-detection image signal of the unit 13. Then, the DCT process is executed in the unit 14, and thereafter the quantizing process is executed in a unit 15.

[0044]

The DCT domain predicting process is executed in a unit 17, while the reference numeral 18 denotes a block memory for storing therein previously decoded block for prediction. In a unit 16, the current DCT block is subtracted from the decoded adjacent block. This

determination is executed in the unit 17. Finally, the predicted DCT block is subjected to an entropy VLC coding process by a unit 20, and the coded bits are written into a bit stream.

In a unit 19, the preceding adjacent block used for prediction is added to the prediction block to restore the current DCT block. Then, the restored DCT block is subjected to a inverse quantizing process and an inverse DCT transform process in the units 21 and 22, respectively. The image data which has been locally decoded is processed by a unit 23. The unit 23 obtains a restored image by adding the preceding frame. A motion detecting and compensating process is executed in a unit 25. The frame memory is used for storing the preceding frame for the motion detecting and compensating process.

[0045]

Fig. 4 is a similar block diagram for DCT domain prediction that has been executed before the quantizing process. An inputted image is subjected to a block sampling process in a unit 26. Then, a unit 27 executes a subtracting process for prediction frame coding, and the subtraction result is inputted to a DCT process by a unit 28 and a quantizing process by a unit 30.

[0046]

A block memory stores therein the preceding block

for the DCT domain predicting process of a unit 31. The DCT block at the present time point is subtracted from the preceding DCT block selected by the unit 29 according to the least bit use rule. A unit 33 executes the inverse quantizing process and a unit 34 executes the entropy VLC coding process.

The restored DCT block is formed by adding the preceding DCT block in a unit 35. A unit 36 executes an inverse DCT transform process, and a restored image is obtained by adding the preceding frame in a unit 37. A unit 38 is a frame memory, and a unit 39 executes motion detection and compensation.

[0047]

Fig. 5 shows an example of detailed explain of the DCT domain. A unit 40 is a block memory for storing therein preceding adjacent blocks for prediction. The current block is inputted to a unit 41, and subtracted from the preceding adjacent DCT block stored in the block memory 40. As a result, four types of predictive DCT blocks are obtained. A block obtained by the unit 42 is called No-Pred block, a block by the unit 43 is Up-Pred block, a block by the unit 44 is Left-Pred block and a block by the unit 45 is Other-Pred block. Therefore, the above four types of blocks are expressed by two bits. For example, "00" expresses the No-Pred block, "01" expresses the Up-

Pred block, "10" expresses the Left-Pred block and "11" expresses the Other-Pred block.

[0048]

The No-Pred block is the current DCT block itself. The Up-Pred block represents a prediction block obtained in a case where the block used for the prediction is the upwardly adjacent DCT block B2. The Left-Pred block represents a prediction block obtained in a case where the block used for the prediction is the leftwardly adjacent DCT block B4. The Other-Pred block represents a prediction block obtained in a case where prediction is effected only on the DC coefficient. In the case of the Other-Pred block, two types of predicting methods exist. That is, an Up-DC-Pred represents a prediction block obtained in a case where a prediction is effected on only the DC coefficient based on the upwardly adjacent DCT block B2. A Left-DC-Pred represents a prediction block obtained in a case where a prediction is effected on only the DC coefficient based on the leftwardly adjacent DCT block B4. In these two cases, an additional one bit is required for designation. The bit is used so that, for example, "0" expresses the Up-DC-Pred and "1" expresses the Left-DC-Pred.

It is possible to make a prediction based on the diagonally adjacent blocks B1 and B3. However, the prediction result is not as good as that made on the blocks

located upwardly or on the left-hand side.

[0049]

All the predicted blocks are inspected and checked by being subjected to the actual entropy coding process in a unit 48. The bits used for different predicted blocks are subjected to a comparison in a unit 49. Finally, a unit 50 determines the DCT block predicted on the basis of the least bit use rule and outputs the predicted DCT block together with a designator bit.

[0050]

Fig. 6 shows a decoder for the DCT domain prediction. A bit stream is inputted to a VLD decoding unit 51 and decoded in a variable length decoding manner. The preceding adjacent DCT block is added so that the DCT block is restored. The preceding adjacent DCT block is identified by a designator bit taken out of the bit stream and used for prediction in the unit 53. A unit 54 is a block memory for storing therein the adjacent DCT block to be used for prediction. A restored DCT block obtained from a unit 52 is outputted to an inverse DCT transform unit 55. The restored image transmitted to a unit 56 is added together with the preceding frame from a unit 57. The unit 57 executes the motion detecting and compensating process. A unit 58 is a frame memory for storing the preceding frame for motion detection and compensation. A unit 59 denotes

a inverse quantizing unit. When the DCT domain predicting process is executed before the quantizing process as indicated by "a" in Fig. 6, the inverse quantizing unit 59 is inserted before the unit 52. However, when the DCT domain predicting process is executed after the quantizing process as shown in Fig. 3, the unit 59 is inserted after the unit 52 as indicated by "b" in Fig. 6.

[0051]

Effects of the Invention:

According to the present invention, a great effect can be produced for the removal or reduction of the redundancy in the DCT domain between adjacent blocks, and consequently the number of bits to be used is reduced, eventually allowing the coding efficiency to be remarkably improved.

[0052]

Referring to Fig. 5 as a detailed prediction example, it can be understood that the predicting process is executed only by using the adjacent block located on the upper side or the left-hand side.

In regard to a sequence including QCIF, bits can be saved by 6.4 % in high order bit rate coding, and bits can be saved by 20 % in low order bit rate coding. Further, bits can be saved by about 10% in another QCIF sequence such as the test sequence of, for example, Akiyo,

Mother and Daughter.

Furthermore, more bits can be saved in CIF and CCIR sequences.

[0053]

In the development process of new image coding techniques with a view to increasing the coding efficiency of the present time, the present invention provides a more efficient, important method based on the image coding techniques of the present time. The invention method requires no complicated means for increasing the coding efficiency, and can be embodied very simply and easily.

Brief Description of the Drawings:

Fig. 1 is a block diagram of a conventional image encoder;

Fig. 2 is an explanatory view of an adaptive DCT domain of intra-frame prediction;

Fig. 3 is a block diagram of an encoder in which a DCT domain predicting process is executed after the quantizing process;

Fig. 4 is a block diagram of an encoder in which a DCT domain predicting process is executed before the quantizing process;

Fig. 5 is a showing a detailed example of the DCT domain prediction; and

Fig. 6 is a block diagram of a decoder for DCT

domain prediction.

Reference Numerals:

1 block sampling

2 motion detection

3 motion compensation

4 DCT transform

5 quantization

6 entropy coding

7 rate controller

8 inverse quantization

9 inverse DCT

10 locally decoded frame memory

11 reference frame memory

12 block sampling

15 quantization

Document Name: Drawing

Fig. 1

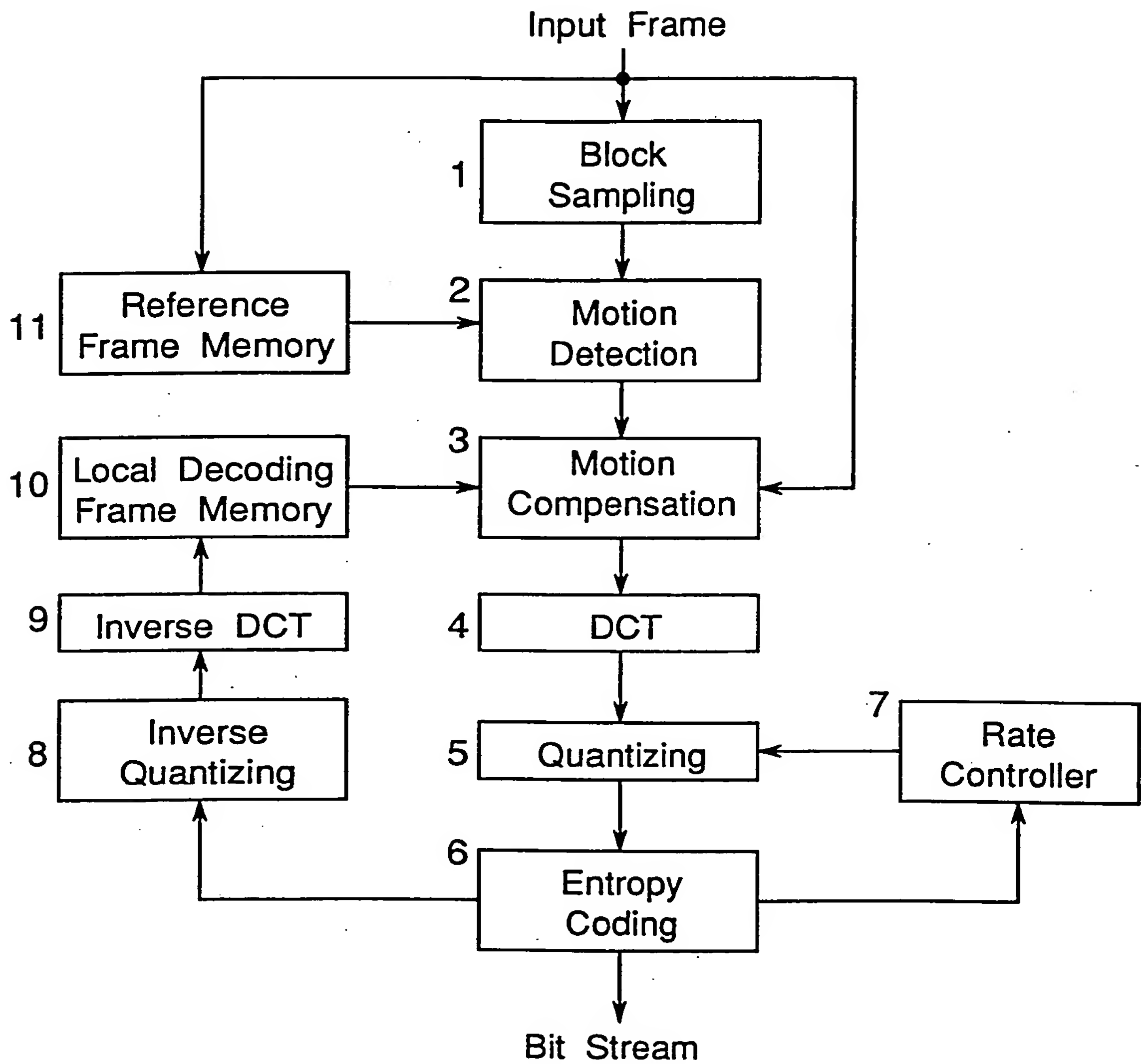


Fig. 2

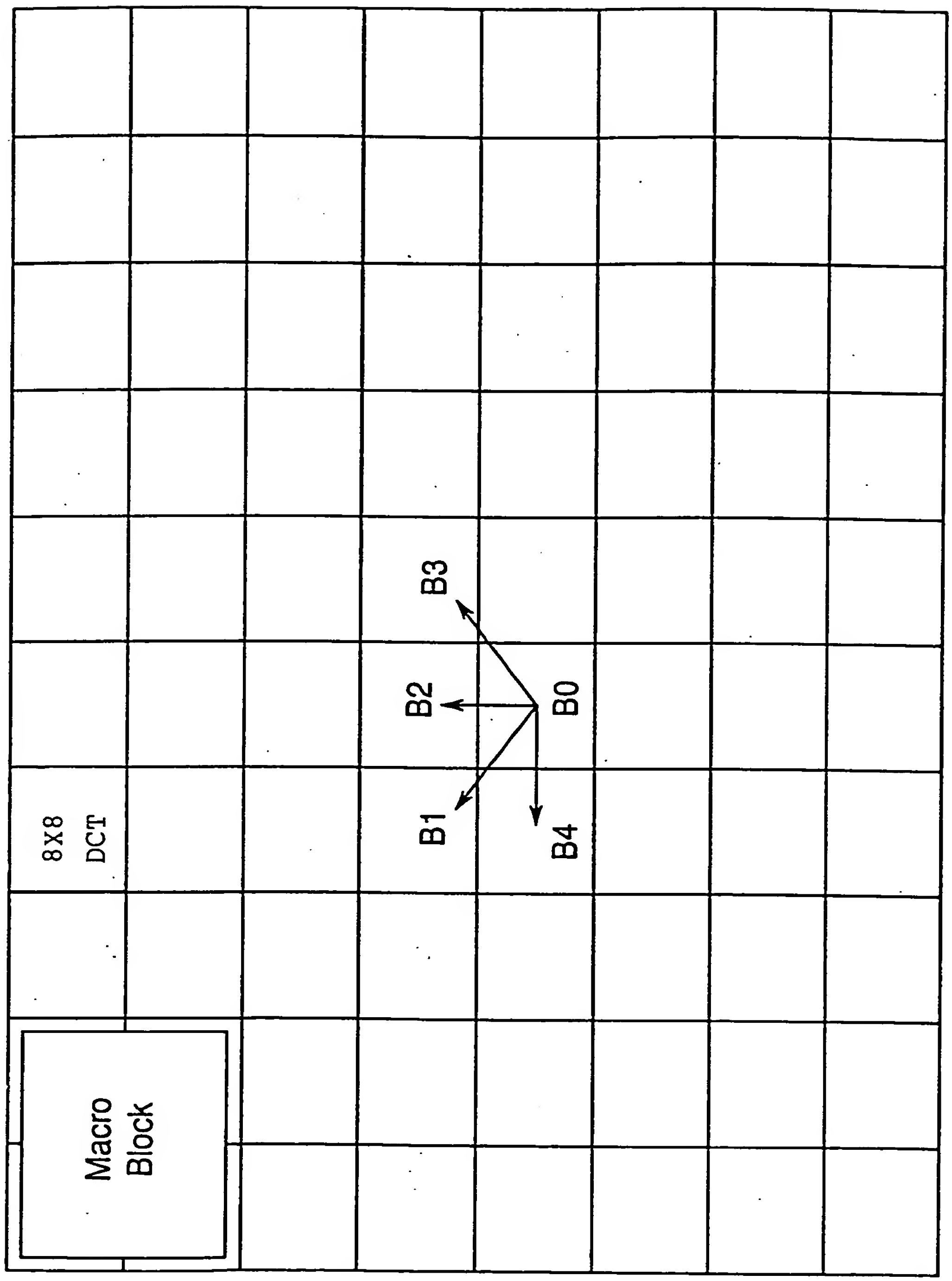
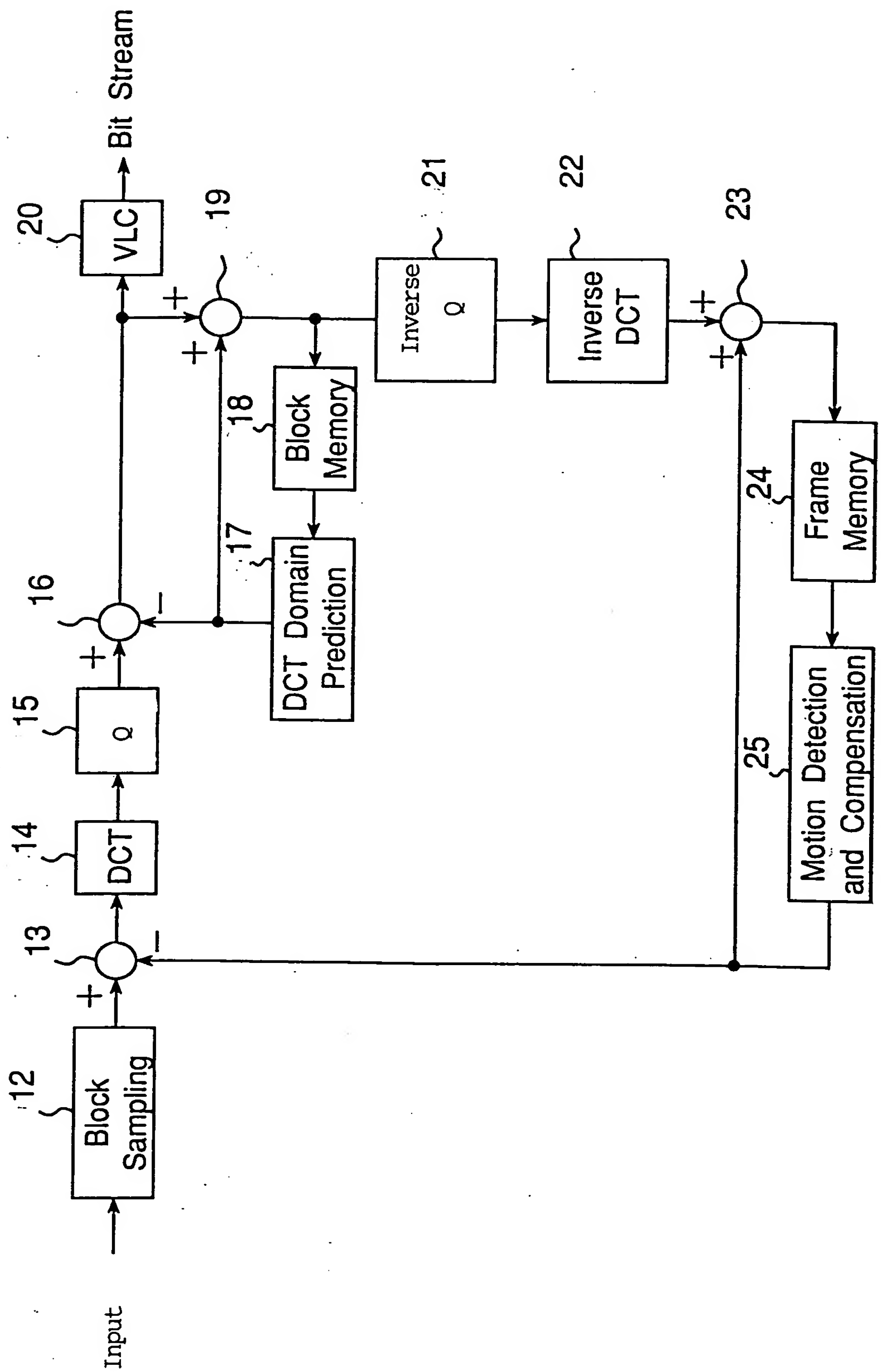


Fig. 3



Input
Block Sampling
12
13
DCT
14
Q
15
16
DCT Domain Prediction
17
Block Memory
18
19
VLC
20
Bit Stream
Inverse Q
21
Inverse DCT
22
23
Frame Memory
24
Motion Detection and Compensation
25

Fig. 4

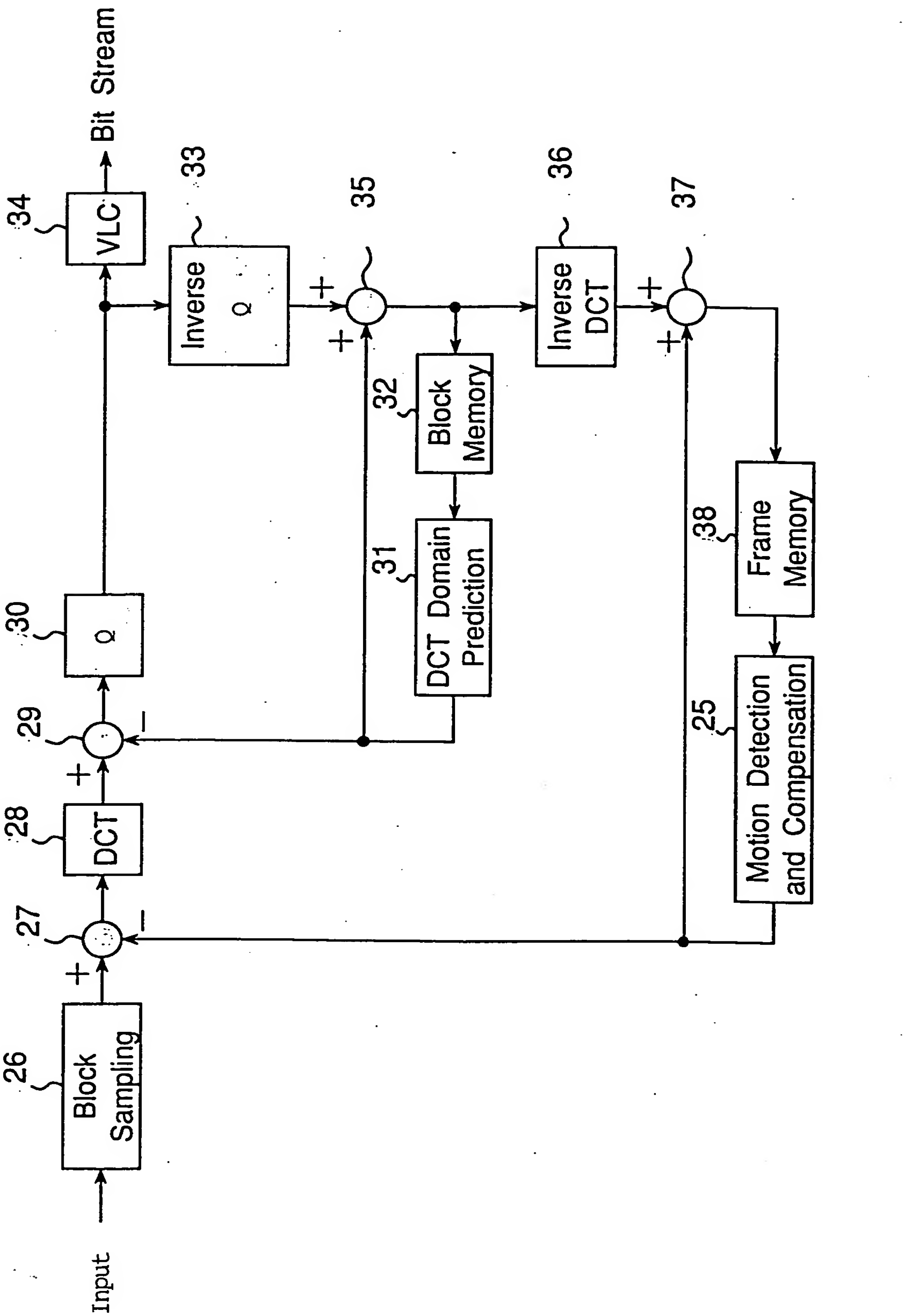
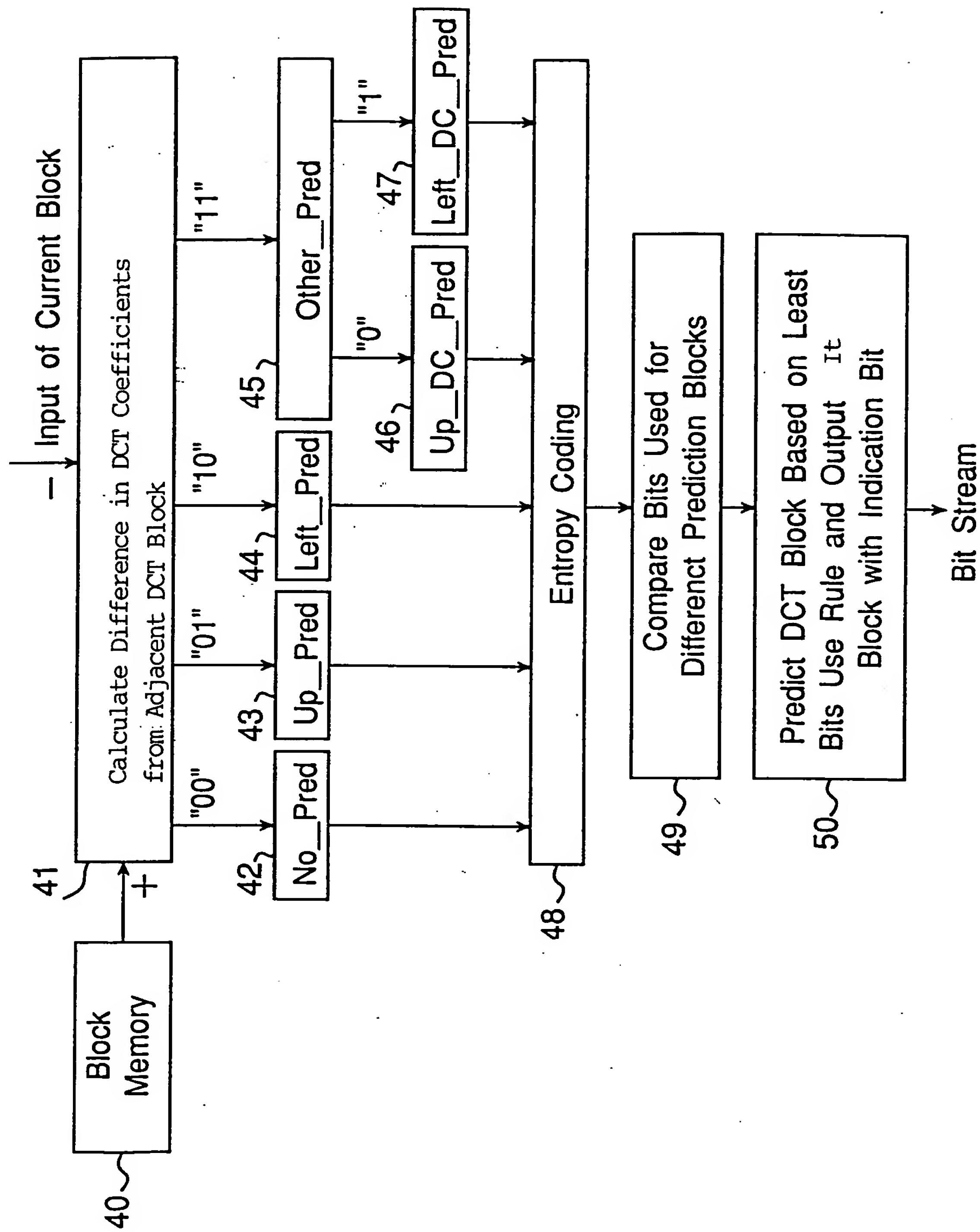
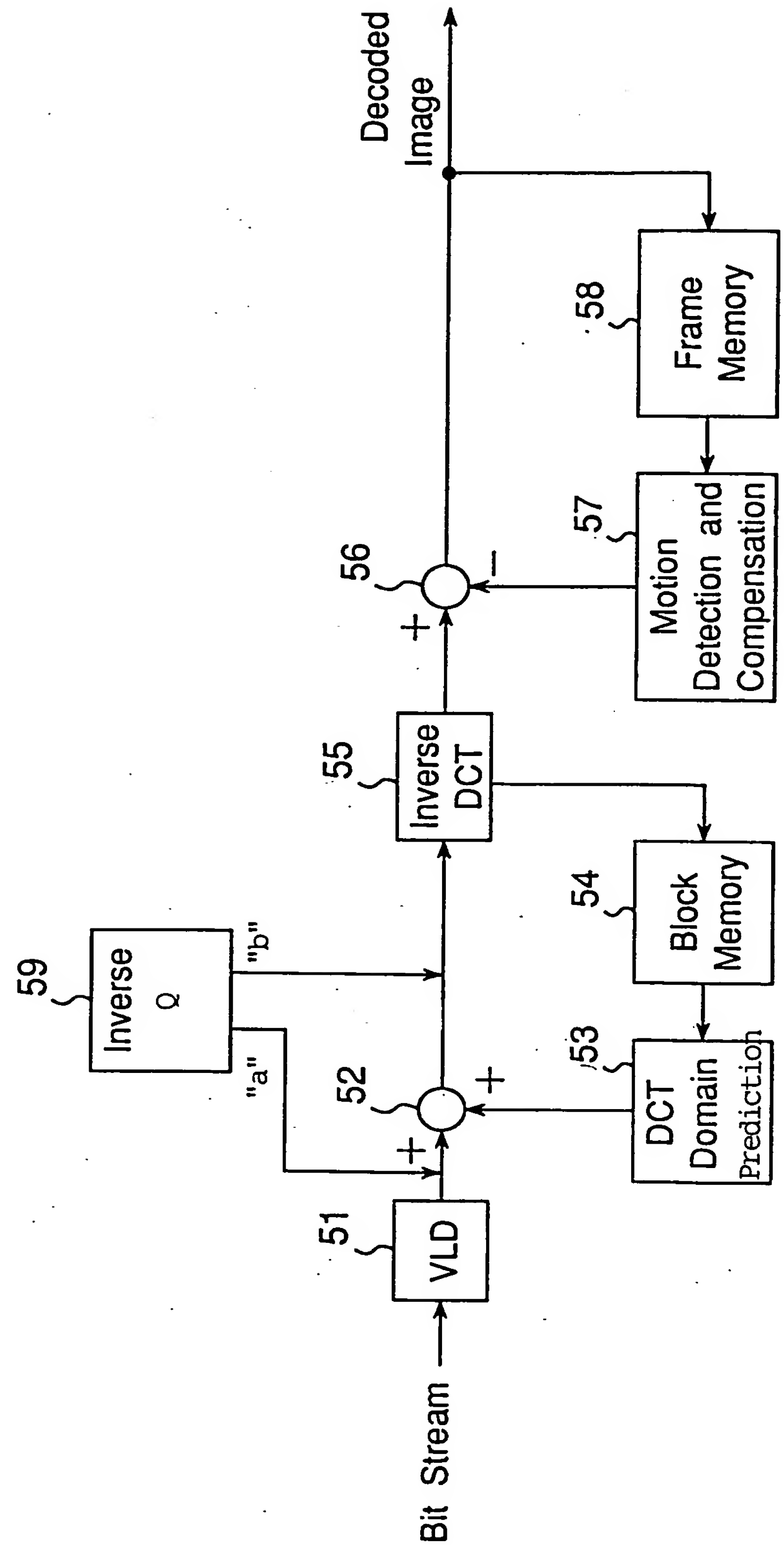

Input
Block Sampling
DCT
Q
VLC
Bit Stream
Inverse Q
Block Memory
DCT Domain Prediction
Inverse DCT
Frame Memory
Motion Detection and Compensation
25
26
27
28
29
30
31
32
33
34
35
36
37
38

Fig. 5



Block Memory
40
Input of Current Block
−
+
Calculate Difference in DCT Coefficients from Adjacent DCT Block
41
"00"
"01"
"10"
"11"
No__Pred
42
Up__Pred
43
Left__Pred
44
Other__Pred
45
"0"
"1"
Up__DC__Pred
46
Left__DC__Pred
47
Entropy Coding
48
Compare Bits Used for Differenct Prediction Blocks
49
Predict DCT Block Based on Least Bits Use Rule and Output It Block with Indication Bit
50
Bit Stream

Fig. 6



Bit Stream
51
VLD
52
+
+
"a"
"b"
59
Inverse Q
53
DCT Domain Prediction
54
Block Memory
55
Inverse DCT
56
+
−
57
Motion Detection and Compensation
58
Frame Memory
Decoded Image

Document Name: Abstract

Abstract:

(Object) In order to efficiently reduce the data of coefficients obtained by a DCT transform.

(Solution) Data quantity of the current DCT block can be reduced by determining a difference between the current DCT block and a past DCT block located on the upper side or left side, and by using the resulting difference as data of the current DCT block.

Selected Figure: Fig. 3

Document Name: Official Correction Data

Corrected Document: Petition for Patent

<Approved or Supplemented Data>

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